



# STATISTICAL PRIMER

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Division of Health Services

Department of Human Resources

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## ADJUSTED RATES

Every now and then we encounter in the literature curious figures called adjusted rates which are supposed to inform us about something and arouse our interest. All they arouse in many people is suspicion. Why, comes the cry from the novice, aren't the simple rates good enough? Why should anyone want to adjust rates in the first place? And isn't something being covered up in the adjustment?

No, the practice is not suspect. Embarrassing truths are not being hidden. And simple, crude rates may not give us the information we need to decide some issue. If the decision involves a comparison among several populations, then there is every reason to compute adjusted rates. Indeed, adjusted rates exist to be used to make comparisons among populations.

In this paper we set out a rationale behind adjusted rates. We will, first, introduce rate adjustment by addressing a set of questions aimed at crude rates and at the so-called direct method; second, describe the indirect method; third, discuss some general principles; and finally, give a few references.

### Crude Rates

What is a crude rate? It is the relative frequency with which some event occurs in a study population, and it commonly takes a standard form such as a number per 100,000. If death were the event and Hope County, N.C. the study population, then the number of deaths per 100,000 population would be the county's crude death rate.

What are the imperfections of crude rates? We must be careful when we use them to compare populations, because crude rates may lead us to wrong conclusions. A crude rate may be misleading if some subset of a population is over or under represented or has an aberrant number of occurrences of the event of interest. Crude rates may not represent accurately the health status of populations. In some applications, crude rates therefore do not permit clear comparisons among study populations.

When should we use crude rates? We should use crude rates whenever we study an absolute problem, such as mortality or disease. Crude rates then measure human suffering. They are plain calls for health services, and they carry an unavoidable moral demand: Serve them. We cannot admit any argument, statistical or otherwise, that distracts us from that moral reality.

When should we adjust rates before comparing populations? We should compute adjustments whenever we suspect that demographic peculiarities in the different populations affect the chances of the event's occurrence. For example, birth rates in two counties may differ greatly because one county has a disproportionate number of young women. Age adjusting the two birth rates to a standard population removes the distorting effects of the dissimilar age



distributions. The difference between the counties' adjusted rates is then due to factors—biological fertility, prenatal care, birth control practices, etc.—other than age. For a second example, suppose the crude death rate in one county is higher than that in a second county, and suppose we ask if something other than race contributes to the difference. We would adjust the death rates for race. Any significant difference between the adjusted rates would then be due to factors other than race.

Plainly stated, the issue in rate adjustment is that of getting an unclouded view of the risk of an event within a study population. The crude rate may not help because it is influenced by the very clouds we would like to remove. In typical applications we must compare several small populations and decide issues which affect the health of our citizens. In these decisions our view of reality must be as clear as possible. If we have reason to place little confidence in the relative magnitudes of crude rates, then we must place our confidence elsewhere, for example in adjusted rates. A rate adjustment is a calculation of a rate which accounts for, and removes, potentially misleading effects caused by the structure of the study population.

### Direct Adjustment

What is the direct method? In the direct method the crude rate becomes adjusted in the sense that it is recalculated by a kind of hybrid process which uses, from the study population, rates specific to categories (or strata) and, from a standard population, sizes of the corresponding categories. For each small study population we apply the category-specific rates to the category sizes of a single standard population. The diverse internal rates of the study populations then act under the common conditions of the standard population.

How does one choose the categories and the standard population? The appropriate categories in a particular application depend on which aspects—age, race, income, place of birth, education, etc.—of a study population are thought to be peculiar. Suppose Example 1 were part of a study of a specific cause of death across various age subsets of a population. The three age categories, (A), (B), and (C), show striking risk differences. (In an actual application we would be comparing this study population with another, and we would want to see if factors other than age contributed to differences between the two.) Age subsets would be appropriate categories, and we would thus "age adjust" to a standard population. The choice of a standard population is usually a matter of tradition and convenience. The state is commonly the standard population when rates for counties are adjusted. The reasons are: (1) it is traditional to ask how a county's crude rate might be transformed if the county had the same population structure as the state, and (2) the state is a natural standard for counties.

What is the intuitive meaning of the rate adjustment formula? Consider the data in Example 1 where the study population is Hope County and the numbers are deaths in age subsets. We see, first, that each age-specific death rate in Hope County is multiplied by the size of the corresponding North Carolina category. Thus the first specific county rate of 100 per 100,000, which is a force of mortality, is applied to the state's population of 1,000,000 in the first stratum; the product is an adjusted number of deaths for the first stratum. Similar products are obtained for all the strata. Second, the sum of the adjusted numbers is divided by the state's population, 4,500,000 in Example 1.



The quotient is a weighted average of the study population's stratum-specific rates. Finally, the weighted average is multiplied by 100,000 for the "per 100,000" aspect of the adjusted rate. The result is Hope County's death rate per 100,000, age-adjusted to the North Carolina population. (The adjusted rate in Example 1 is vastly greater than the crude rate. The difference is due principally to the atypical category (C). When some strata contain small numbers, as (C) does, then adjusted rates are unreliable. If (C) were combined with category (B), then the adjusted rate would be 290.4 per 100,000.)

#### Example 1

Direct Adjustment in Which the Crude  
and Adjusted Rates are Quite Different

(All Rates are Per 100,000)

Study Population			Standard Population
No. People in Each Category	No. of Events	Category- Specific Rate	No. People in Each Category
(A) 10,000	10	100	1,000,000
(B) 20,000	60	300	3,000,000
(C) 10*	9*	90,000*	500,000
30,010	79		4,500,000

$$\text{Crude rate} = \frac{79}{30,010}(100,000) = 263.25 \text{ per } 100,000$$

Adjusted rate (by the direct method)

$$= \frac{\frac{100}{100,000}(1,000,000) + \frac{300}{100,000}(3,000,000) + \frac{90,000}{100,000}(500,000)}{4,500,000}(100,000)$$

$$= 10,222.22 \text{ per } 100,000$$

The study population could be Hope County in North Carolina; the standard population, the State of North Carolina; categories (A), (B), and (C), three age groups.

\*Category (C)'s peculiar size and rate are dealt with below.

### Indirect Adjustment

The indirect method of rate adjustment is also a hybrid sort of calculation, but it uses rates from the standard population and category sizes from the study population. And there is a second step: The standard population's crude rate is multiplied by the ratio of observed to expected numbers of events in the study population. The product is the indirect adjusted rate.

In Example 2 we may suppose deaths in a county were counted and the county's population were grouped into three categories. The state is the standard population.

The calculations show that 70.10 deaths were expected in the county assuming the county was subject to the state's sequence of rates. That is, the expected number is calculated by multiplying each category-specific rate in the standard population by the category size in the study population. (The ingredients of direct adjustment were the opposite: The rates came from the study population, and the category sizes came from the standard population.)

The indirect adjusted death rate is

$$333.33 \frac{79}{70.10} = 375.65$$

which is the state's crude death rate multiplied by the ratio of the observed number of deaths for the county to the expected number for the county. It is important to note that indirect adjustment does not require that one know category-specific numbers of events in the study population, even though these are shown in Example 2. The important specific rates and numbers of events are entirely within the standard population.

Example 2  
Indirect Adjustment  
(All Rates are Per 100,000)

Study Population (County)			Standard Population (State)		
No. People in Each Category	No. of Deaths	Category- Specific Rate	No. People in Each Category	No. of Deaths	Category- Specific Rate
(A) 10,000	10		10,000,000	10,000	100
(B) 20,000	60		30,000,000	90,000	300
(C) 10	9		5,000,000	50,000	1,000
30,010	79		45,000,000	150,000	

Crude Death Rate:

$$\frac{79}{30,010}(100,000) = 263.25$$

Crude Death Rate:

$$\frac{150,000}{45,000,000}(100,000) = 333.33$$

Observed Number of Deaths in the County = 79

Expected Number of Deaths in the County

$$\begin{aligned}
 &= \frac{100}{100,000}(10,000) + \frac{300}{100,000}(20,000) + \frac{1,000}{100,000}(10) \\
 &= 10 + 60 + 0.10 = 70.10
 \end{aligned}$$

Direct adjustment is "direct" in the sense that the category-specific rates of the study population are applied directly. The term "indirect" should not be taken as a logical opposite; it denotes merely that the category-specific rates of the study population are not used in the adjustment.



The indirect method of adjustment is especially recommended in two situations: (1) When category-specific rates in the study population are unreliable. A loss of precision occurs when some categories of the study population are small (e.g., Examples 1 and 2). In Example 2, one of the categories has only ten people, and that specific rate can hardly be stable. Direct adjustment would require that we use that (probably unstable) rate; the indirect method, however, does not require the rate. (2) When category-specific rates in the study population are not known. This situation is not uncommon. If a population is very small or not well enumerated, then events in particular strata may never have been counted, even though the strata population sizes and the total number of events are known. The specific rates cannot be calculated, so the direct method is not possible. But adjustment by the indirect method is feasible because, as in (1), specific rates from the study population are not required.

To illustrate the use of indirect adjustment in making comparisons, let us suppose the data in Example 3 were observed for a second county in a study similar to Example 2.

Example 3  
Indirect Adjustment  
(All Rates are Per 100,000)

Study Population (County)			Standard Population (State)		
No. People in Each Category	No. of Deaths	Category- Specific Rate	No. People in Each Category	No. of Deaths	Category- Specific Rate
(A) 10,000	10		10,000,000	10,000	100
(B) 40,000	120		30,000,000	90,000	300
(C) 10	9		5,000,000	50,000	1,000
50,010	139		45,000,000	150,000	

Crude Death Rate: 277.94 per 100,000

Adjusted Death Rate: 356.13 per 100,000

The reader should verify the rates (see page 4 for instructions) and, in particular, note that the two counties have the same category-specific rates. The only difference of real importance is the size of category (B). (Even if the 139 deaths in this second county had been distributed in a vastly different manner, the indirect adjusted rate would still have been 356.13. Why?)

Here is a summary table:

County	Crude Death Rate	Death Rate Adjusted by the Indirect Method
I	263.25	375.65
II	277.94	356.13



We note, first, that both counties have crude rates less than the state's crude rate of 333.33; second, that both counties have crude rates less than the adjusted rates; and third, that the county with the higher adjusted rate has the lower crude rate.

We conclude that (1) both counties enjoy, at present, low crude death rates; in the future they would have rising death rates if their populations change to resemble the state's population in the variable of stratification (age); (2) the low crude rates derive from favorable distributions of the population across age; and (3) County I, which at present has slightly fewer deaths per 100,000 than County II, may become somewhat worse off in the future if the populations of the counties change to resemble the state's population in the variable of stratification.

The first and third conclusions are possible because indirect adjustment depends to some extent on the distribution of the population across strata. Neither the crude rates nor the identical category-specific rates could have given us these insights.

Direct and indirect methods are not the only approaches to the adjustment of rates. The references will lead the reader to other methods.

### Generalizations

The purpose of adjustment, by any method, is to permit us to compare study populations. The direct and the indirect methods are both perfectly good; both give rates that can, in the proper circumstances, be used to make valid comparisons. The choice of methods is not a question of which is "better" than the other; it is a matter of which is appropriate.

With these admonitions firmly in mind, we can offer the following suggestions on the use of direct and indirect methods: The direct method should be used whenever possible, that is, if all category sizes in the study population are reasonably large and all category-specific rates are known. If only a few categories are small it is usually worthwhile to choose a coarser stratification and then proceed with the direct method. If direct adjustment is not feasible, for example if some category sizes are small or if some category-specific rates are unknown, then the indirect method should be used.

The reader should look again at Example 1 and feel startled to note that direct adjustment there violates the principles in the preceding paragraph. While Example 1 does illustrate the computation of the directly adjusted rate, the data are not appropriate to the direct method. Category (C) is much too small. The same set of data, addressed in Example 2, is properly processed by the indirect method.

Do not be too eager to adjust rates. Whenever we have the data we can certainly compare study populations stratum-by-stratum using category-specific rates. This simple, straightforward method sometimes proves to be the best way to make decisions.

Do not compare adjusted rates based on different standards. Such comparisons are invalid. For example, every year a state may publish death rates for counties adjusted to the state's population for that particular year. A state's population changes continually, so it follows that the standard population probably changes from year to year. Such adjusted rates for counties may be compared within the same year because they are adjusted to the same standard, but adjusted rates from different years may not be compared because

they are adjusted to different standards. By the same reasoning, we may not compare adjusted rates from two or more states unless all use the same standard.

Any type of adjustment is done according to an appropriate mathematical formula, and the formula does not change. The particular numbers in the calculation will, of course, vary with the particular application. Any adjustment must begin with the choices of variable of interest, strata, and standard population; only after making these choices do we know the numbers to use in the calculation.

The following contrasts between direct and indirect adjustments can be made.

- Direct
1. The calculations use rates from the study population and category sizes from the standard population.
  2. The rates of the study population are applied directly in the computations of adjusted rates.
  3. If two study populations have, stratum by stratum, the same specific rates, then their direct adjusted rates will be equal; their population distributions will not matter.
  4. The method implicitly assumes the category-specific rates in the study population are reliable.

Indirect

The calculations use rates from the standard population and category sizes from the study population.

The rates of the <sup>study</sup>~~standard~~ population are not used in the computations of adjusted rates.

Category-specific rates of the study populations are irrelevant; the adjustment is for differences in population distribution.

The method is especially useful when stratum-specific rates are unreliable or nonexistent.



## REFERENCES

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- Tukey, John W., (1976). "Statistical Mapping: What Should not be Plotted," Proceedings of the 1976 Workshop on Automated Cartography and Epidemiology pp 18-26, National Center for Health Statistics, U.S. Department of Health, Education, and Welfare. Appendix 1 contains four helpful examples of direct and indirect adjustments.





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